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"Transmission of Data in Boreholes"

2  
3 This invention relates to a method of and apparatus for  
4 transmitting data in boreholes such as oil wells.

5  
6 To optimise the efficiency both of the detection of oil  
7 reserves and the recovery of these reserves, it is  
8 important to obtain as much detailed information as  
9 possible about the ambient environmental conditions at  
10 the base of an oil well. This information is obtained  
11 by a variety of sensors located at the base of a well  
12 when required. The information obtained by the sensors  
13 may be transmitted to the surface of an open well using  
14 sonic waves which propagate through the drilling mud.

15  
16 However, this method may only be employed during  
17 drilling when sufficient hydraulic power is available  
18 to generate the signal at the base of the well. During  
19 well testing and production this power source is not  
20 available and a valve or plug may be inserted in the  
21 well resulting in there being no direct fluid path  
22 through the centre of the well from the base of the  
23 well to the surface.

24  
25 One situation to which this particularly applies is in

1 shut-in testing where a shut-in valve is included in  
2 the well. A test generally consists of flowing the  
3 well, thus drawing down the well pressure, and then  
4 suddenly stopping the flow by closing the shut-in  
5 valve. Information regarding the potential of the  
6 reservoir can be derived from examination of the  
7 ensuing pressure rise/time characteristic, requiring a  
8 pressure gauge beneath the valve. The shut-in is best  
9 done down-hole rather than at the surface, to avoid  
10 well-bore storage effects which are difficult to  
11 compensate for.

12

13 It is possible to adapt valves to produce a hydraulic  
14 or electrical path through the valve to enable the  
15 transmission of signals from a sensor below the valve  
16 to a receiver above the valve. The path through the  
17 valve terminates in a connector which is suitable for  
18 connection to the receiver, the receiver in turn being  
19 connected via a cable to the surface of the well.  
20 However, this system is extremely difficult to operate  
21 as the small connector on the surface of the valve is  
22 extremely difficult to contact with the receiver and a  
23 considerable length of time is taken to make a suitable  
24 connection.

25

26 Accordingly, the present invention provides a method of  
27 transmitting data in a borehole, the method comprising  
28 providing an electric signal representative of the data  
29 to be transmitted, converting said electric signal into  
30 a sonic signal, propagating said sonic signal along an  
31 elongate member, and processing the sonic signal for  
32 onward transmission.

33

34 The processing of the sonic signal may for example be  
35 at the surface, or it may be downhole by retransmission

1 r it may be by electronic data storage for later  
2 pick-up.

4 In another aspect, the invention provides apparatus for  
5 transmitting data in a borehole, the apparatus  
6 comprising a transmitter and a receiver; the  
7 transmitter including means for converting data  
8 parameters into an electric signal and first transducer  
9 means responsive to said electric signal to generate an  
10 acoustic signal, the first transducer means being  
11 adapted for physical coupling to an elongate member  
12 extending along the borehole whereby the acoustic  
13 signal is propagated in said elongate member; the  
14 receiver comprising second transducer means adapted for  
15 physical coupling to said elongate member to produce an  
16 electrical output corresponding to said acoustic  
17 signal, and signal processing means connected to  
18 receive said output and operative to process the data  
19 into a condition for onward transmission.

20  
21 An embodiment of the invention will now be described,  
22 by way of example only, with reference to the drawings,  
23 in which:

24  
25 Fig. 1 is a schematic cross-sectional side  
26 view of apparatus in accordance with the  
27 invention in use in a well;

28 Fig. 2 is a block diagram of a transmitter  
29 forming part of Fig. 1;

30 Fig. 3 is a block diagram of a receiver  
31 forming part of Fig. 1; and

32 Fig. 4 is a block diagram of an alternative  
33 form of receiver.

34  
35 Referring to Fig. 1, a drill stem 1 is sealed to a well

1 bore 23 by a packer 2, leaving an annulus 3 to contain  
2 mud and well control fluid. Any production fluids will  
3 pass up the centre of the drill stem 1 via a shut-in  
4 valve 4. The present embodiment utilises the invention  
5 to pass data relating to the fluid pressure in the  
6 drill stem bore 24 below the shut-in valve 4 to a  
7 location above it.

8  
9 A transmitter designated generally at 6 is positioned  
10 in an external recess 25 of the drill stem 1. The  
11 transmitter 6 is powered by a battery 7 and includes a  
12 pressure transducer 9 communicating with a lower bore  
13 24 via a port 8. The analog pressure signal generated  
14 by the transducer 9 passes to an electronics module 10  
15 in which it is digitised and serially encoded for  
16 transmission by a carrier frequency, suitably of 2-10  
17 kHz. The resulting bursts of carrier are applied to a  
18 magnetostrictive transducer 11 comprising a coil formed  
19 around a core whose ends are rigidly fixed to the drill  
20 stem 1 at axially spaced locations. The digitally  
21 coded data is thus transformed into a longitudinal  
22 sonic wave in the drill stem 1.

23  
24 A receiver generally designated at 12 is housed in an  
25 external recess 26 of the drill stem 1 at a location  
26 above the shut-in valve 4. The receiver 12 comprises a  
27 filter 13 and transducer 14 connected to an electronics  
28 module 15 powered by a battery 17.

29  
30 The output of the electronics module 15 drives a signal  
31 coil 16.

32  
33 The filter 13 is a mechanical band-pass filter tuned to  
34 the data carrier frequency, and serves to remove some  
35 of the acoustic noise in the drill stem 1 which could

1 otherwise swamp the electronics. The transducer 14 is  
2 a piezoelectric element. The filter 13 and transducer  
3 14 are mechanically coupled in series, and the  
4 combination is rigidly mounted at its ends to the drill  
5 stem 1, aligned with the longitudinal axis of the  
6 latter. Thus, the transducer 14 provides an electrical  
7 output representative of the sonic data signal.

8  
9 A preferred method of retrieving the data is to store  
10 it in memory in the electronics module 15, for  
11 retrieval at a convenient time by a pick-up tool 5.  
12 This avoids the problems inherent in providing a  
13 real-time data path along the whole length of the well.  
14 The pick-up tool 5 is lowered on a cable or wireline 22  
15 to locate in a nipple 18 which causes the signal in the  
16 receiver 16 to be aligned with a coil 19 in the pick-up  
17 tool 5. The coils 16 and 19 are then inductively  
18 coupled, allowing the data to be transferred to the  
19 pick-up tool 5 serially on a suitable carrier wave to  
20 the pick-up tool 5.

21  
22 The pick-up tool 5 includes an electronics package 20  
23 which is arranged to send a transmit command to the  
24 receiver 12 when the tool 5 is seated on the nipple 18.  
25 The electronics package 20 may be arranged to decode  
26 and store the data if the tool is on wireline, or to  
27 re-transmit the data if the tool is on cable. In the  
28 latter case, power may be supplied to the tool via the  
29 cable; otherwise, power is derived from an internal  
30 battery 21.

31  
32 Referring now to Fig. 2, the transmitter electronics  
33 module 10 in the present embodiment comprises a signal  
34 conditioning circuit 30, a digitising and encoding  
35 circuit 31, and a current driver 32. The details of

1 these circuits do not form part of the present  
2 invention, and suitable circuitry will be readily  
3 apparent to those skilled in the art. The transducer  
4 11 has a coil 33 connected to the current driver 32 and  
5 formed round a core schematically indicated at 34.  
6 Suitably, the core is a laminated rod of nickel of  
7 about 25 mm diameter. The length of the rod is chosen  
8 to suit the desired sonic frequency which is suitably  
9 in the range 100 Hz to 10kHz, preferably 2-6 kHz.

10  
11 In the receiver, as seen in Fig. 3, the electronics  
12 module 15 comprises in series a passive band-pass  
13 filter 35, an active band-pass filter 36, and a  
14 phase-locked loop 37 supplying clean data signals to a  
15 decoder 38. The decoded data is stored in memory 39.  
16 When a pick-up tool 5 is positioned and activated,  
17 carrier frequency induced in the signal coil 16 is  
18 detected at 40 to enable control logic 41 to read data  
19 from memory 39 for transmission via encoder 42, current  
20 driver 43, and the signal coil 16.

21  
22 The alternative receiver shown in Fig. 4 uses a similar  
23 mechanical filter 13, transducer 14, and electronic  
24 filters 35 and 36. In this case, however, the filtered  
25 data signal is not stored but is used to control a  
26 current driver 44 driving a magnetostrictive transducer  
27 45 for sonic re-transmission further along the drill  
28 stem.

29  
30 Thus, the invention enables data to be transferred by  
31 sonic transmission past a valve or the like and then  
32 further handled by (a) storage in memory for later  
33 retrieval, (b) real-time transmission electrically by  
34 cable, or (c) sonic re-transmission.

35

1 Modifications may be made within the scope of the  
2 invention. For example, the transmitter transducer may  
3 impart a torsional, rather than a longitudinal, sonic  
4 vibration to the drill stem. Transducers of other than  
5 magnetostrictive type may be used, such as  
6 piezoelectric crystals or polymers.

7  
8 Although described with particular reference to shut-in  
9 testing in producing wells, the invention may be  
10 applied to any situation where a borehole is  
11 obstructed. The medium for sonic transmission need not  
12 be a drill stem but could, for instance, be casing or  
13 other tubular.

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